Explosively formed penetrators are testing the limits of the current generation of vehicle armour. Adam Baddeley examines the threat and the emerging generation of solutions

MRAP is soon to be replaced by MRAP II ©DoD

Defeating EFPs

Explosive formed projectiles/ penetrators (EFP) are the latest and most deadly weapon, designed for use against hitherto largely invulnerable Mine Resistant Ambush Protected (MRAP) type vehicles used for patrolling in Iraq and Afghanistan.

The core EFP design packs explosives behind a concave metal dish – typically made of copper or similar malleable alloy with a relatively low melting point. In simple IED-type situations, a single explosion creates a solid shot of molten metal capable of hitting vehicles some distance away and penetrating considerable distance through conventional rolled homogeneous armour. The warhead design is such that it can be used in off-road devices – fired directly at the side armour – as well as in under-body mines. The latter is more typical for Iraq and Afghanistan, while the former came to prominence during operations in the Balkans. While gaining prominence as IED devices, EFP warheads already have a strong presence in conventional military weapon systems, allowing for more complex implementations such as top attacks. Different flavours of warheads design also produce different effects, such as a basic slug, long-rod penetrators or multiple fragments to create a high-velocity shrapnel effect.

Some of these more complex, factory-produced designs have entered the current theatre of operations from external sources such as Iran, which is often either the country of origin or a conduit for weapon systems acquired further afield. Barbed comments from the US came to a head in mid-2007 when the Bush administration said that Iran's extraterritorial Qods Force were supplying Shia insurgents and were directly responsible for the deaths of US servicemen. It must be assumed that Iran is not the only supplier or source, as Sunni-insurgents also use this category of weapon.

As an off-road solution, EFPs are not area-effect blast weapons; they must be fired accurately against a target, which is their weakness. The use of homegrown EFPs as IEDs creates, by necessity, simplified designs. Detonation is controlled by cable, radio control, TV or remote control, and these can be disrupted in the same way as any other IED. The designers of such devices typically lack the means to test and refine aerodynamic designs at an instrumented range to ensure they can be fired with an acceptable degree of accuracy. That means the weapon has to be close to its target to stand any chance of hitting it. Typically, the high speed of convoys and individual patrol vehicles often means the only feasible attack will be point at which speed must be reduced, such as corners or crossroads. One way around this is to increase the number of EFPs in a ripple effect, but this takes more time or more personnel to emplace, creates more disruption to the earth and adds to the chance of detection.

EFPs are not exclusively an IED weapon. A number of countries manufacture and field "ambush" EFPs, which are built around a tripod and remotely detonated. Systemised off-road EFPs could also rely on a cueing system, using acoustic sensors to fire up an

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infra-red sensor that could act with sufficient speed to trigger an attack. These include the Czech PD Mi-PK, the French MIACAH F1 and the Russian TM-83, which fire directly onto the target. Others are more complex, opting for a top attack solution. The Textron Sensor Fuzed Weapon system consists of ten sub-munitions each firing four EFP projectiles, and was used during the 2003 invasion of Iraq. The US Selectable Lightweight Attack Munition (M2/M3/M4 SLAM) can provide all three options – top attack, mine or off-road attack, depending on its implementation. Later models of the Talley M72 LAW also use EFPs.

Outside the US, Russian firms have undertaken work to match new EFP warheads with legacy shoulder-launched anti-tank weapons, such as Temp-10 based on the RPG-7 with an enlarged-calibre 50mm EFP warhead. The warhead detonates after it has been launched to create the penetrating effect.

Defending against EFPs

The US MRAP II programme has protection against EFPs as one of its key goals. The MRAP II will provide enhanced levels of protection against direct attacks and under-body blasts compared with current variants, and particularly against EFPs. One of the immediate responses to the EFP threat has been to simply increase the amount of armour carried; MRAP and MRAP-type vehicle have seen their weight go up, with minimal increase to the payload. The MaxxPro Plus, for example, is five tones heavier than its predecessor.

One of the issues in developing protection against EFPs is the poor definition of the threat, however. In IED terms, the threat is so diverse that terms of reference expressed in, for example, a NATO STANAG, are largely absent. The US Army's quick reaction response to EFPs was to task the Army Research Lab (ARL) with developing better armour. The result was the Frag Kit 6, an appliqué solution originally developed for use with HMMWVs. This solution was neither svelte nor elegant, adding about 30cm to the side of a vehicle. Considerable weight was also added, as the composite armour weighs in excess of 100lb per square foot (400kg per square metre) and mechanical assist devices were required to open doors thus equipped. The UK, by comparison, has agonised over the use of the Snatch Land Rover because it provides valuable access to narrow Iraqi and Afghanistan streets, which balances its limited protection qualities. By comparison, adding Frag Kit 6 to an MRAP I, makes it too wide to be legally driven, even on well-proportioned US roads. In addition, the potential damage to roads and bridges from such weighty vehicles is considerable.

MRAP II

Seeking additional protection against EFP threats beyond that provided by first-generation MRAPs with add-on armour, the DoD embarked upon MRAP II, issuing a pre-solicitation in July 2007. The Army Research Laboratory (ARL) worked to ensure the technologies used in Frag Kit 6 would be available to MRAP II designers, and several competitors offered solutions which were tested. The vehicles used were: BAE Systems/Armor Holding's Caiman; Blackwater USA's Grizzly APC with Ares EXO Scale appliqué armour; Force Dynamics' reinforced Cougar; Ceradyne, Oshkosh and Ideal Innovations' Bull, produced on an Oshkosh Medium Tactical Vehicle Replacement (MTVR) chassis; GDL Canada's upgraded BAE OMC RG-31; Navistar Defense's improved MaxxPro; Textron's M1117 with armour upgrades; and Protected Vehicles' upgraded Golan vehicle. In some designs the desire to maximize protection is such that no side doors are used; troops leave either by the rear door or via emergency hatches on top.

Only the Caiman and the Bull passed the assessment and received contracts. A common factor for both was that they weighed in excess of 18,000kg. In late 2007 and early 2008 the DoD issued contracts for up to 20,500 MARP II vehicles.

BAE Systems' Caiman design was selected in two variants: the Category I MRAP II test vehicles based on the company's Caiman 6x6 design, and the Category II MRAP II test vehicles based on the company's RG33 6x6 vehicle designed for support operations in restricted spaces, specifically urban environments. The Category II vehicle is a more complex, reconfigurable design and would be used for a range of roles from ambulance to explosive ordnance disposal.

Matt Riddle, vice president of Wheeled Vehicle Programs said at the time, "The RG33 and Caiman vehicles have the right balance of payload capability, automotive performance and blast protection, and have proven extremely capable of handling the significantly increased requirements of MRAP-II. Our designs offer mobility upgrades that significantly increase payload capacity and enable the integration of superior survivability enhancements across the threat spectrum."

It is not just the US military that is concerned about EFP, and companies outside the US are actively trying to develop solutions. Rheinmetall Land Systems describes its GeFaS Advanced Protective Vehicle System as protected against EFPs. Another German solution for one aspect of the EFP conundrum has been developed by IBD Deisenroth Engineering, namely the Advanced Modular Armour Protection System Roof Protection (AMAP-R) which is designed to provide a low-weight solution against top attack EFP. It consists of a layered solution reported to weigh as little as 25-120kg per square metre, depending on threat levels. The firm has also sold counter-EFP capable armour to Canada on its LAV III-based Coyote and Bison vehicles and Leopard 1C2. The company is also providing the modular armour package for the new Puma IFV for the Bundeswehr. It has been reported that, as part of its modular armour package, the Piranha V will have EFP protection. Armour firms are understandably reticent about their counter-EFP armour designs. Of them, Israel Military Industries (IMI) has the only widely marketed solution – its Steel Wall design which is being offered as an IED and conventional EFP defence.

Defensive Aid Suites may be one solution in the future, but at the current time the ultra high velocity of EFPs, both in their IED and off-road forms, are fired from extremely small distances and thus offer little time to respond. Somewhat ironically, Rafael's Trophy systems is actually said to use EFPs as the basis of its hard kill system, cued by a radar system.

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